wealth, lies in the command of the Indian Ocean which it assures to that country.

It would be premature to say that Persia has been divided, but a long step has been taken towards that consummation. The convention provides that, in case of the non-payment of interest on certain debts already contracted through the official British and Russian banks of Persia, either of the signatory Powers may take over the customs service and administer it in favour of the creditors. This provision, which on its face appears of minor importance, may lead to actual, though unavowed, partition of the Shah's domain. Persia is not in the habit of paying its debts. If the entire customs service, as well as the concessions for railroads, mines, and so forth, is divided between the foreign Powers, small autonomy remains to Persia.

Some one must eventually exercise control over the unassigned "buffer" which England has left between herself and Russia, and the two countries must eventually agree upon a common frontier. It is perhaps not unreasonable to suppose that ere many decades England will concede northwestern Afghanistan to Russia in return for fuller rights in southwestern Persia around the Persian Gulf. When that is accomplished many causes of friction will vanish; for the political boundary will coincide with a somewhat pronounced physical boundary—on the east, the central mountains of Afghanistan; in the centre, the deserts of eastern Persia; and on the west, the high mountains of western Persia.

EXPERIMENTAL PHYSIOGRAPHY.

BY

GEORGE D. HUBBARD.

A beginning in experimental physiography was made at Ohio State University* during the past year. A basement room in the geologic building was fitted up with drains, bins of sand, clay, cement, and various other materials, and river and ocean tanks, for running and standing water. The first problem chosen was that of the aggrading and degrading stream, not so much to discover

*The author was ably assisted by Mr. A. E. Moody, an advanced student in the department, to whom thanks are due for many suggestions.

new laws as to test book knowledge and to compare the controlled experiment with the processes in nature's laboratory. The student's growth and the results obtained fully justify the outlay of money, time, and thought. And, further, some new things have been seen in miniature which ought now to be verified in the study of the life-size forms in nature.

THE INITIAL VALLEY.

Into a water-tight tank two feet wide, sixteen inches deep, and eighteen feet long was put by hand a weak concrete to form a mature valley. The general trend of the valley was straight, but the line of greatest depth was made to swing from side to side by constructing spurs of the weak cement alternately from the opposite sides of the valley. This piece of construction occupied all but eighteen to twenty inches at each end of the tank, portions which were left, at the upper end for a clay depository and at the lower end for a lake basin around the outlet. The lower end of the tank was fixed on a substantial block, while the upper end rested on a twelve-inch steel jackscrew, so set that the slope of the tank could be varied from zero to one foot in seventeen, or about $3\frac{1}{4}°$, equivalent to three hundred and ten feet per mile. To begin with, the valley was given a slope of one inch in seventeen feet, or about 26 feet per mile.

Aggradation.—Dry fire-clay of unequal fineness was heaped into the upper end of the tank above the valley and the finest spray obtainable from a garden hose was turned on. The clay was washed down the mature rock valley, and with it the stream aggraded the valley. Progress was so slow on account of the coarser clay and the stream that we were obliged to use, that we steepened the slope to two inches in the length of the valley. With this slope, aggradation proceeded more rapidly, and the valley was filled level full at the upper end and nearly so at the lower end. In order to complete aggradation, we raised the level in the lake at the outlet at about the rate the valley was aggraded, by lengthening a perforated stopper.

Degradation.—When a satisfactory stage of filling had been reached no more clay was added, and the stream's burden became so light at the source that it began down-cutting. No change was made in slope or water supply except as water-pressure varied, but degradation continued until a youthful valley, with an interesting series of terraces, was carved in the flood-plain, and the stream touched the rock-bed of the valley at many points.

This completed the experiment, which had occupied a winter

term of thirteen weeks. Three photographs were taken—one near the beginning of the aggradational work (Fig. 1), one just after degradation had begun (Fig. 2), and one at the completion of the experiment (Fig. 3). These are introduced into the text and show the general features of each phase in the experiment.

Fig. 1.

Results of the Experiment.

Aggradation Fans.—It is particularly the results of our work that I desire to present. While the aggradation process was going on, two peculiarities of the method attracted our attention. The first of these was the making of an asymmetrical, fan-like feature on the flood-plain. While the stream was flowing in its channel, it

gradually deposited on the inside of a curve until the channel became choked, and the stream, being pushed over the opposite bank, was forced to take a new course. It then proceeded to construct a systematic asymmetrical fan over previous flood-plain deposits, and finally again came to flow temporarily in a rather definite channel across the fan. The latter possessed a very gentle slope, which seems much exaggerated in the photograph. Almost immediately after the establishment of a satisfactory channel, the deposition on the inside of curves would again begin and the entire process would be repeated. So constantly was this process in operation that there was always at least one such fan under construction in the fifteen or sixteen feet of flood-plain, and not infrequently three or four were building. The photograph (Fig. 1) shows a number of them. So numerous were they that at times they constituted about the only forms of accumulation. They are probably a feature of the more rapidly-flowing streams, and not of such as the Mississippi. They overlapped each other in part, and might have furnished excellent miniature illustrations in section of cross-bedding. Our clay was all so similar, and so little consolidated in the flood-plain, that sections cut through the strata did not reveal the interval structure.

Pits or Depressions.—The second peculiarity was the formation and preservation of pits or depressions on the flood-plain. Frequently, beneath eddies at angles in the stream or at the junction of two channels, a pit an inch deep or less would be dug out, and subsequently, when the stream withdrew bodily from its shallow, ill-defined channel, the pit would remain unfilled (Fig. 1 and Fig. 2). A depression one-half inch deep and one to two and one-half inches across is a small feature, but in an aggradational flood-plain less than a foot wide it is very conspicuous. It seems probable that this pit-making process may have been operative on outwash plains in some of the larger valleys of central New York and adjacent Pennsylvania. Many so-called kettles in the Susquehanna and Chemung gravel-plains now persist as pits, sometimes as swamps. A detached ice block is supposed to have been buried or surrounded with outwash gravel, and then to have melted out, leaving a kettle-like depression in the gravel. But if our experiment was analogous with nature in this particular, nothing more than the normal pit-forming process of overloaded streams need be called in to explain such kettles. Following the habit of those in glacial valley plains, our kettles would not retain water, until muddy water had soaked down in them several times, leaving a film of fine clay to plug the interstices between the coarser clay-pieces. Both of these peculiarities

are little known in the field, and further observation must be made to determine whether they arise from the peculiar conditions of the experiment or are normal in aggrading streams.

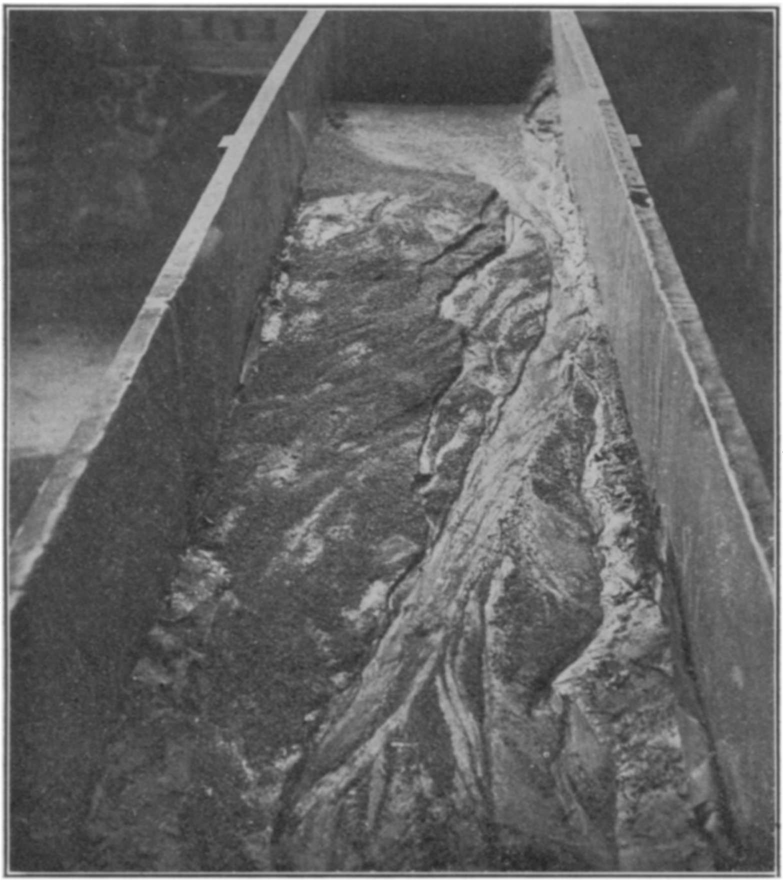

FIG. 2.

A Cause for Stream Migration.—In confirmation of the excellent study of Mr. R. F. Griggs* these experiments showed that the stream, by depositing sand bars in its channel on the inside of its curves, forces itself to cut on the outside and thus to enlarge its meander curves. This, as it is well known, is not the only cause of meanders, but is one of several causes. It seems to be more effective in streams of moderate velocity. Rapid streams, after making

*BULLETIN, Amer. Geog. Soc. Mar., '06. Vol. XXXVIII, pp. 168–177.

a bar, push it away and re-straighten their courses, and the more sluggish ones are turned aside by many slight obstructions. Further evidence of the marked influence of "overload" upon meandering appeared when the clay supply was withdrawn. The stream thereafter made substantial progress in straightening its course, and soon for several feet it ran in a "bee line," until in its down-cutting it found the spur ledges and was obliged to turn aside.

Slope, Water Supply and Load.—Slope and water supply have been considered the chief factors that determine whether a stream shall aggrade or degrade. Our experiments demonstrated clearly that there are three factors entering into a stream's habit—viz., slope, water supply, and waste supply or load. As long as our miniature river was kept supplied with waste (all it could carry) it continued to aggrade. We left the slope the same so far as the tank was concerned, throughout all the experiment, save while experimenting the first few days, as described below, and kept the water supply fairly constant. With these constant variations in the supply of waste varied the habit of the stream. An abundance of clay always gave an aggrading stream, but as soon as the supply of clay was cut off the stream began to degrade. We temporarily increased the slope; but, as long as the clay supply was abundant, the stream persisted in aggrading; then we temporarily increased the water supply, and, as long as the larger volume found abundance of clay to carry, the stream's habit remained unchanged. It aggraded. Having abundance of waste within reach of the stream, we decreased the water volume. This did not increase deposition, but rather decreased it, because with diminished volume came diminished velocity and carrying power, hence the stream could not pick up as much as formerly. It was still loaded to the maximum, but the maximum did not mean as much clay as with greater volume. Then we decreased temporarily the slope, which, though often stated to increase deposition, in this instance actually decreased it because the stream was then unable to start so much material as formerly, and, of course, had less to drop. Our stream did all its aggrading and then all its degrading, with no change either of slope or volume, save those just mentioned, but solely a change in clay supply.

The conclusions concerning the relative importance of slope, water supply, and load and their relation to the habit of the stream (aggrading or degrading) may be summarized as follows:

A stream having access to abundance of rock waste will aggrade faster with increased water supply and also with increased slope, and will aggrade more slowly with decrease in either water supply

or slope. But an underloaded, hence a degrading, stream if supplied with more waste may be made to aggrade with neither decrease in slope nor in water supply; or may be made to aggrade by decreasing water supply or slope, thus reducing carrying power below the load. Habit is a matter of adjustment or balance of the three factors; and the habit is changed in a stream with changes of slope or water

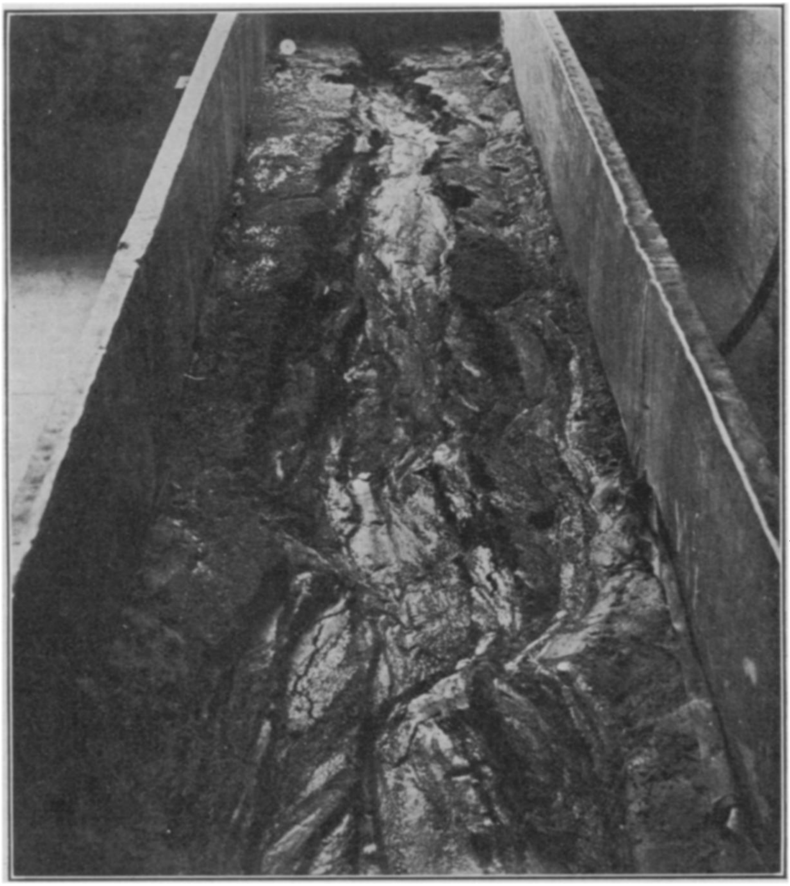

FIG. 3.

supply (1) when the clay supply is abundant to overloading, (2) when clay supply is very insufficient. But in the first case changes are simply quantitative, while in the second they are qualitative.

Double Channels.—When aggradation was stopped by cutting off the supply of aggrading material the stream forthwith began degrading. In places there were two or three channels—a braided

course—but in each the stream excavated a channel, and thus there came to be not only terraces along the valley sides, but remnants of the flood-plain with lower new flood-plain all around. Ultimately the stronger stream gained the mastery and took all the water, leaving a deserted channel through the plain only a little above the one occupied by the stream.

I had tried to account for this feature when observed in the present valley of the Susquehanna in southern New York, and am now satisfied that it may be explained as illustrated by our experiment.

Preservation of Terraces.—In striking confirmation of the explanation so carefully worked out by Prof. Davis for alluvial terraces standing above present flood-plains, the experimental river carved series of terraces as it gradually entrenched itself in its bed of deposits, but subsequently cut out most of them which were not defended by rock spurs (compare Fig. 2 and Fig. 3). Not all terraces remaining to the end of the experiment were behind or above rock points, but none that were removed by stream undercutting were tipped with rock. At the end only an occasional terrace remained which had no rock defense, but possibly if more time had been allowed all remnants within reach of the stream would have disappeared. The defense was a very evident feature in every extended series of terraces; but a few single or two-step terraces unprotected still remained. Certainly chances for their permanence were very few.

Terrace Persistence Down Stream.—Very soon after degradation began it was noted that the terraces were not persistently at the same height above the new flood-plain, but that they seemed to come in strong and run out down stream (Fig. 2). This is an expectable phenomenon, because the stream, now degrading, was continually reducing its steepness of slope. Its highest aggradational plain and the flood plains at subsequent lower levels were not parallel. Degradation being more rapid upstream, each terrace must decrease in height and then run out, when the plane of any new flood-plain met downstream with the plane of the top aggradational plain or any previously formed flood-plain. And where the planes of any two flood-plains intersected, the terrace between them would be shallower until it finally ran out.

In Conclusion.—The experiment served to call attention to several things rarely or never seen on larger flood-plains. Things concealed by their smallness in comparison with the larger and more commonly seen features have been brought out and emphasized. It must not

be forgotten, however, that some features seen may be peculiar to a stream in clay loosely laid, but would not be found in nature. Field work is now necessary to verify some of these purely observational points, and, until so verified the latter may be considered as facts belonging to the experimental stream, but not necessarily to all streams whether free or not.

OHIO STATE UNIVERSITY.

ANGELO HEILPRIN.

Professor Heilprin died in New York city on July 17th last. Born in Hungary in 1853, he was only 54 years of age. He was in the prime of life, and his enthusiasm for scientific research and joy in the life-work he had chosen had suffered no abatement. Though his reputation as a geographer and naturalist was international, his untimely loss is felt with especial poignancy at home.

Heilprin came of a talented family. His grandfather, Phineas M. Heilprin, was a recognized authority in Hebraic and philosophical literature in the early part of the last century. His father, Michael Heilprin, was an erudite scholar and held a high position in the fields of Biblical interpretation and literary criticism. Michael Heilprin and his family came to America in 1856, and in 1860 young Heilprin's education began in a public school of Brooklyn. The boy was precocious; his passionate love of knowledge and his facility in acquiring it were innate. His intellectual tendencies and talent were fostered and promoted by his home training, and while still in his teens his receptive mind had embraced a wide range of knowledge. Mr. Louis E. Levy, in the *Memoir* read before the Franklin Institute of Philadelphia in September last, wrote that before young Heilprin had reached his twentieth year he was a capable associate with his elder brother Louis in the work of their father as revising editor of the American Cyclopædia, contributing also a number of original articles, notably the biographical sketch of John Tyndall.

The year 1876 found Heilprin in London studying the natural sciences at the Royal School of Mines with Huxley as his guide in biology, Ethridge in palæontology, and Judd in geology. The young man received the Forbes Medal for proficiency in biology and palæontology. Later he studied in Paris; wandered on foot